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Brief report: Imaginative drawing in children with Autism Spectrum Disorder and learning disabilities

Abstract

Here we examine imaginative drawing abilities in children with Autism Spectrum Disorder (ASD) and learning disabilities (LD) under several conditions: spontaneous production, with use of a template, and combining two real entities to form an ‘unreal’ entity. Sixteen children in each group, matched on mental and chronological age, were asked to draw a number of ‘impossible’ pictures of humans and dogs. Children with ASD were impaired in spontaneous drawings and included fewer impossible features than children with LD, but there was no difference when a template was provided. An autism-specific deficit was revealed in the task involving combining entities. Results suggest that children with ASD do not have a general imaginative deficit; impairment is instead related to planning demands.

Keywords: drawing, imagination, planning, autism, learning disabilities

Brief report: Imaginative drawing in children with Autism Spectrum Disorder and learning disabilities

Imagination requires the ability to shift from reality and ‘decouple’ (Leslie, 1987), and underpins both cognitive and emotional development (Harris, 2000). Children with Autism Spectrum Disorder (ASD) have documented impairment in imagination, reflected in repetitive behavior (Bodfish, Symons, Parker, & Lewis, 2000; American Psychiatric Association, 2013; Wing & Gould, 1979) and difficulties with pretense and symbolic play (Jarrold, Boucher, & Smith, 1996; Wolfberg, 2009; see Jarrold, 2003 for a review). One way imagination has been assessed in children with ASD is by analyzing creative drawings, which can provide a rich way to assess conceptual knowledge (Freeman, 1980; Cox, 2005) without the requirement of verbal explanations that can be difficult for children with language impairment.

In one of the first studies to test imagination in ASD in this way, Scott and Baron-Cohen (1996) showed that children with ASD were significantly worse at drawing ‘impossible’ men or houses (see Karmiloff-Smith, 1990), than a comparison group with learning disabilities (LD). The authors suggested that the representation of real objects and imagined objects depends on different neurocognitive processes, and thus children with ASD show a ‘pure’ deficit in imagining unreal entities. However, Leavers & Harris (1998) challenged this interpretation, and posited instead that children with ASD may have specific difficulty deploying new and complex visuo-spatial plans (e.g. a planning deficit), and thus revert back to familiar graphic schema which are easier to execute. In their study, participants were given templates to complete, such as a headless man. The rationale was that providing contextual information would reduce the planning demands required of the participants, and thus make the task more directly targeted at identifying imagination. When given such cues,

children with ASD were just as able to depict impossible entities as typically developing (TD) children and children with LD, suggesting that imagination may not be as impaired as Scott & Baron-Cohen (1996) claimed and is instead related to planning. To tease between these hypotheses, it is necessary to compare these distinct methodologies in the *same* population of children, to account for the wide heterogeneity of ASD (Folstein & Rosen-Sheidley, 2001).

Other evidence has shown impairment by children with ASD in imaginative drawing, but only when compared to TD children. For instance, Low, Goddard, & Melser (2009) found that children with ASD produced fewer imaginative drawings relative to a TD control group. Imaginative drawing was linked to generativity in ASD, as measured by how frequently children produced novel uses of objects and meanings of simple patterns. The authors also performed a covariance relationship analysis (see Jose, 2003), which showed that planning mediated the relationship between imaginative drawing and generativity. Craig, Baron-Cohen, and Scott (2001) found deficits in children with ASD relative to TD children when asked to draw a ‘man with two heads’ and combine entities such as a car and train into one ‘unreal’ object. A group of children with LD, however, also showed impairment, suggesting this may be an effect of cognitive delay. Children with LD are thus a particularly interesting comparison group to include in the current study.

The drawing differences of children with ASD in prior work can not be linked to ability per se, as drawing ability of individuals with ASD is equal to peers who are matched on mental age (Charman and Baron-Cohen, 1993; Eames and Cox, 1994; Allen & Chambers, 2011). However, differences have been detected in drawing style, in terms of a local rather than global approach consistent with weak central coherence (Mottron, Belleville, & M  nard, 1999; Booth, Charlton, Hughes, & Happ  , 2003), and overlap in pictures of humans but not

nonhumans (Fein, Lucci, & Waterhouse, 1990). Lee and Hobson (2006) also showed that children with ASD tended to draw similar pictures of humans, but were able to produce visually distinguishable drawings of houses, which may reflect specific difficulty depicting animate entities.

Overall, the prior literature has identified several different processes involved in imaginative drawing tasks: ‘pure’ imagination, generativity, and planning. Baron-Cohen and colleagues view imagination in ASD as a pure deficit that stems from difficulty decoupling beliefs from reality. This means that at a fundamental level, individuals with ASD are not able to mentally represent novel entities because they need to recruit theory of mind skills such as pretense. Generativity is a related but separable component (Scott & Baron-Cohen, 1996) that encompasses the ability to create novel ideas. Its role in imaginative tasks has been debated. Low et al. found that the ability to derive novel uses for objects and determine multiple referents of abstract patterns related to imaginative drawing performance, but Scott & Baron-Cohen did not find any impairment by children with ASD in a ‘function of a brick’ or verbal fluency task when compared to clinical controls, even though the latter could create imaginative pictures. It is difficult to assess the direct role of generativity as failure to produce creative pictures could reflect difficulties at the basic level of mental representation (‘pure’ deficit) or with producing multiple novel features (generativity); we thus do not directly test generativity here. A third component in imaginative drawing tasks that can directly be assessed, and which we focus upon here, is planning. Planning is necessary to translate a mental representation into graphical output, and requires successful construction and execution of a motor schema.

To address the open questions in the literature and account for the disparate findings across different population samples, here we test the same children with ASD and children

with LD using several imaginative drawing conditions. We vary the extent to which planning demands are required, to specifically test the pure imagination vs. planning hypotheses. In two conditions, children are asked to draw figures from scratch, which requires a relatively high level of planning. Children are asked to produce spontaneous pictures of ‘strange and funny looking’ creatures (to avoid any potential difficulty comprehending the term ‘impossible’; see Low, Goddard, & Melser, 2009), and are also asked to combine, for instance, a car and train to produce a novel entity. Including both types of task can inform whether any potential imaginative deficits are specific to novel graphic schema, or extend to novel pictures that are derived from the modification of two familiar schemes (Craig, Baron-Cohen & Scott, 2001). A third condition requires a lower level of planning as children are given ‘headless’ templates to complete; in this way they do not have to construct and execute a full graphic plan and the task demands are minimized, but they still must produce imaginative elements (see Leavers & Harris, 1998). If children with ASD have difficulty with high and low planning tasks, this would support a pure imaginative deficit and failure at the level of representation. If they are successful with the template task but show difficulty in the high planning conditions, however, this would support a planning hypothesis. To examine whether an animate deficit is specific to humans, we also ask children to draw dogs. These measures will allow us to test: 1) whether imagination deficits in ASD are pure, or instead relate to planning demands, and 2) if they are specific to ASD or stem from cognitive delay more broadly.

Method

Participants

Sixteen children with ASD (14 males, 2 females; *M* age: 13.6 years, range: 12.5–15.7 years) and sixteen children with LD (10 males, 6 females; *M* age: 13.0 years, range: 11.6–

15.7) were matched on chronological age (CA) and also receptive vocabulary as measured by the British Picture Vocabulary Scale (BPVS-II; Dunn, Dunn, Whetton & Burley, 1997). The mean mental age (MA) was 8.3 years (range: 5.4–11.1 years) for children with ASD and 8.3 years (range 5.6-11.4 years) for children with LD. One-way ANOVAs confirmed that neither CA nor MA differed between groups. Participants were recruited from a Special Needs Secondary School in Merseyside, England. All children with ASD received a clinical diagnosis of ASD by a qualified educational or clinical psychologist, using standardized instruments (i.e. Autism Diagnostic Observation Scale and Autism Diagnostic Interview - Revised; Lord, Rutter, DiLavore & Risi, 2002; Lord, Rutter & Le Couteur, 1994) and expert clinical judgment. Autism diagnoses were confirmed in the ASD group and ruled out in the LD group using the Social Communication Questionnaire (SCQ, Rutter, Bailey & Lord, 2003), which was completed by each participant's class teacher (M score ASD = 26.7, range: 22-31; M score MLD = 4.1, range 2-6).

Materials

Children were provided with 6 blank sheets of paper, a pencil and eraser. For the cued (template) condition, they were also given pre-drawn templates consisting of a man without a head and a dog without a head.

Procedure

Participants were tested individually in schools and were situated in a quiet area to minimize distractions. They were seated opposite the experimenter and materials were placed within their reach. Every child received three conditions. The Spontaneous condition was always administered first to minimize perseverative responding in the children with ASD; because the templates contained largely possible bodies of a human and a dog (missing only the head), children could potentially use these as a reference for subsequent drawings

(thereby underestimating their ability to draw imaginative features across the body). The Cued condition, Unreal Category Mixing condition, and Real Picture drawings followed in a fixed order. Two coders blind to group and hypotheses rated all the drawings. All drawings were coded as ‘pass/fail’ and the proportion of impossible features was calculated. Full coding criteria for all drawing types can be found in Appendix A.

Spontaneous ‘Impossible’ Drawings. Following Low, Goddard and Melser (2009), children were shown pictures of a number of people/dogs, walking towards a magic door. They were then read a passage of text designed to set the scene and increase the contextually available information: ‘The people (dogs) are walking towards a magic door, when they go through the magic door they will be changed into strange and funny looking people (dogs) that you won’t have seen before. Can you draw me a picture of a person (dog) that has gone through the magic door making them look strange and funny looking?’

Order of dog/human drawings was counterbalanced, and the magic door backstory was re-introduced before the second drawing. Children were praised after completing each picture, regardless of content.

Cued ‘Impossible’ Pictures. Children were asked to complete templates of a human without a head and a dog without a head to make them look ‘impossible’. The experimenter said, ‘Here is a picture of a person (dog) without a head. Can you complete it so that it is strange and funny looking?’ Order was counterbalanced.

Unreal Category Mixing. Children were also required to complete drawings that involved unreal category mixing (as per Craig, Baron-Cohen & Scott, 2001). The aim was to identify whether children with ASD were able to draw pictures that involved combining their representations of real entities to form a single unreal entity and required a high level of planning. Children were required to draw a creature that was half human, - half dog and a

vehicle that was half train - half car (counterbalanced for order). The experimenter said, 'Now I would like you to draw a creature (vehicle) that you might find through the magic door that is half human – half dog (half train - half car).'

Real Pictures. Children were also asked to draw pictures of a real human and a real dog (counterbalanced for order) as a gauge of the child's normal drawing style and also to provide a comparison for cases where it was unclear whether the child had drawn an 'impossible' picture. These pictures were always drawn last to minimize any potential perseveration from executing a motor plan for a familiar entity to the impossible entities. The experimenter said, 'Now I would like you to draw me a picture of a real person (dog).'

Drawing Ability. To provide a crude measure of drawing ability (accuracy), each real man and dog drawing was rank ordered against others of the same type to determine relative drawing ability of all participants. Raters were asked to organize each of the drawing types from best (most realistic) to worst (least realistic), which provided rank orders (1–32) for both types of drawing).

Results

Reliability

Cohen's Kappa was calculated to analyse the inter-rater reliability between the two coders for every picture. All values were greater than 0.85, showing excellent reliability, so the scoring of Rater 1 was used for the remainder of the analysis.¹

Spontaneous and Cued 'Impossible' Drawings

¹ A number of the drawings produced by one child could not be interpreted as it was unclear what each feature included in the picture had intended to represent. Therefore, only the drawings for the spontaneous human, real human and human-dog were analyzed for this participant. In addition, one child with ASD was unwilling to complete any spontaneous drawing, but he was willing to complete the template drawings, which were included in the analysis.

Separate chi-square analyses on the pass rate for spontaneous impossible drawings revealed significant group differences for both the spontaneous dog, $\chi^2(1, N=31)=6.61$, $p=.01$, $\Phi=.46$, and spontaneous human figure, $\chi^2(1, N=32)=3.87$, $p<.05$, $\Phi=.35$. In contrast, no group differences were obtained for the cued dog, $\chi^2(1, N=31)=1.70$, $p=.19$, $\Phi=.19$, and cued human, $\chi^2(1, N=31)=.86$, $p=.35$, $\Phi=.17$, drawings (see Figure 1). McNemar tests were performed on trial type (e.g. human vs. dog) to probe for differences within each group; no significant differences were obtained for spontaneous or cued drawings. Thus, children performed equally well in the human and dog trials. Examples of drawings can be found in Appendix B.

Number of features. The number of impossible features was expressed as a proportion of impossible features divided by the total number of features drawn for each figure. A mixed ANOVA was conducted for the spontaneous drawings with figure type (human, dog) as a within factor and group as a between factor. A significant main effect of group was obtained ($F(1, 30) = 56.96$, $p < .001$, $\eta p^2 = .655$), but there was no main effect of figure type or interaction. For the spontaneous human drawings, children with ASD produced 21% impossible features and children with LD produced 41% impossible features. For the spontaneous dog drawings, children with ASD produced 23% impossible features and children with LD produced 45% impossible features.

A mixed ANOVA showed no significant group or figure type differences for the number of impossible features drawn for the cued human (ASD: 33%, LD: 47%) and cued dog drawings (ASD: 31%, LD: 39%).

We also calculated the number of features produced overall (combined imaginative and non-imaginative) for each drawing. No significant group differences were obtained for any of the drawing types (spontaneous human: ASD 5.7, LD 5.7; spontaneous dog: ASD 6.6,

LD 6.2; train/car: ASD 4.1, LD 4.8; human/dog: ASD 5.9, LD 6.2; cued human: ASD 3.1, LD 3.1; cued dog: ASD 2.9, LD 3.5; real human: ASD 5.3, LD 5.8; real dog: ASD 6.3, LD 6.3).

Real human and dog drawings

Both groups correctly omitted impossible features in their real drawings (29/31 ASD, 32/32 LD). A significant group difference was observed for the number of features changed between the real human and spontaneous human drawings ($F(1, 29) = 6.89, p = .014, \eta p^2 = .192$), with children with ASD changing fewer features overall (1.3) than the LD group (2.6).

Ability. Mann-Whitney tests confirmed that the rank order was not statistically significant between groups for either the real dog or real human figures, thus the two groups were equated for drawing ability.

Unreal category mixing

Chi-square analyses were performed to assess group differences in pass rates on the human-dog and train-car hybrid figures. The success rates for the human-dog hybrid were 56.2% for children with ASD and 93.8% for children with LD, a significant difference, $\chi^2(1, N = 32) = 6.0, p = .014, \Phi = .43$. For the train-car figure, the success rates were 31.2% for children with ASD compared to 68.8% for children with LD, also a significant group difference, $\chi^2(1, N = 32) = 4.5, p = .034, \Phi = .38$. A MacNemar test performed on trial type with both groups combined revealed a significant difference, $\chi^2(1, N = 32) = 4.9, p = .027$, indicating that the human-dog figures were easier for all participants to construct. A summary of performance across the different conditions can be found in Table 1.

--- Insert Table 1 around here ---

Relation between variables

Correlation analyses were performed to detect relationships between MA, CA, performance on the SCQ and performance on the drawing tasks. A Pearson's correlation revealed a significant relationship between MA and pass rate for the spontaneous human ($r=.796, p<.001$), cued human ($r=.768, p<.001$), spontaneous dog ($r=.564, p<.029$), cued dog ($r=.619, p=.0141$) and human-dog ($r=.533, p=.033$) drawings for children with ASD only. The SCQ was negatively related to cued human drawing performance only ($r=-.546, p=.035$) for children with ASD (as a higher score on the SCQ indicates more autism characteristics), and CA was unrelated to all measures. Table 2 depicts all correlation values. If the more stringent Bonferroni correction is applied to correct for multiple comparisons (alpha value of .003), only the correlations between MA and spontaneous human and cued human performance, respectively, remain significant. However, critics argue that this procedure inflates the risk of type II errors (e.g. Nakagawa, 2004; Rothman, 1990) or is unnecessary (Perneger, 1998). There was no relation between MA, CA, SCQ, and any of the drawing measures for the group with LD.

Comparison across conditions

We also tested the differences between groups in the high (spontaneous and unreal category mixing) and low (cued) planning conditions. Given the lack of significant differences between trial type (e.g. dog and human), data was collapsed and paired t-tests were conducted. For the group with ASD, there was a significant difference between the unreal category mixing and cued conditions ($t(15) = .034$) and a trend towards significance between the spontaneous and cued conditions ($t(15) = .082$). We found no significant differences across conditions in the LD group.

Discussion

We investigated whether the failure of children with ASD to draw imaginative pictures stems from a fundamentally distinct neuro-cognitive system (as per Scott & Baron-Cohen, 1996), or planning difficulty (as per Leavers & Harris, 1998). We tested these hypotheses by comparing spontaneous and prompted drawing conditions requiring drawing of real and impossible stimuli in the *same* population of children. Our results indicate that children with ASD are able to complete templates to make entities look ‘strange and funny’ just as successfully as children with LD, however they are unable to spontaneously do so. These results provide support for the planning hypothesis, rather than a pure deficit in imagination. Our LD comparison group was able to depict impossible entities across all tasks, showing that the differences in the ASD group are not simply due to cognitive delay.

Our results complement both Scott & Baron-Cohen (1996) *and* Leavers & Harris (1998) because we respectively confirmed their basic findings. We also showed that imaginative deficits are not specific to constructing completely novel entities, but occur when individuals with ASD are also asked to combine familiar entities into something new. It is likely that difficulty with planning underscores poor performance in the spontaneous and unreal category mixing conditions because they require that children continually monitor and update a sequence of planned actions, a process known to be impaired in ASD (Hill, 2004; Hughes, 1996). Poor planning has been observed in drawing production (Booth, Charlton, Hughes, & Happé, 2003), during tasks such as the Tower of Hanoi (Ozonoff, Pennington, & Rogers, 1991), and at the neural level during motor actions (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). Although it is possible that differences in generativity might contribute to the pattern of performance we obtained (see Boucher, 2007), it cannot account for the success in the template condition, where both groups were able to generate imaginative entities. Our data do not speak to the relative influence of generativity, thus it will be

important for future research to include measures of generativity in addition to planning manipulations in order to ascertain the specific contribution of each. One possibility is to combine these aspects within a single paradigm (rather than using a separate generativity measure such as the novel uses task in Low et al.). Children could be provided with a drawing of a circle vs. a more detailed template to manipulate planning and the instructions could vary to probe for renderings of real *and* ‘unreal’ stimuli. In this way, one could tease apart the effects of planning from generation of novel real vs. novel imaginative entities.

We did not find any differences between drawing type (people vs. dogs), suggesting any divergence in drawing content is not specific to humans, but instead reflects the underlying processes specific to novel, imaginative, depictions. It will be interesting for future work to assess a wide variety of animate and inanimate stimuli to probe for further potential differences. Both groups found it more difficult to create a train-car rather than human-dog figure, which we attribute to the fact that they were asked to draw both dogs and people before the category mixing condition, whereas any schema for the train-car was not previously primed and therefore had to be initiated from scratch. It is also possible that the train-car was more difficult to depict because the two components were more perceptually similar to each other.

Links to mental age only for the ASD group suggest that receptive language ability mediates success on the impossible drawings, and that these children may be recruiting language to help guide them through the execution of a novel graphic schema. Thus, the underlying skills supporting imaginative drawing appear to differ between our clinical groups. Future work should assess the extent to which broader cognitive and language skills support imaginative drawing processes in ASD. More specifically, children could be measured longitudinally to determine whether language abilities predict subsequent

performance in imaginative tasks across development. It would also be useful to compare performance across conditions that recruit language comprehension and ask children to draw nameable figures to performance in tasks where the items to be constructed are not nameable and thus do not rely upon prior linguistic knowledge (see Callaghan, 2000).

Of course, there are limitations to the present study. We matched our ASD group to children with LD, but did not include a typically developing comparison sample. Although we intentionally tried to avoid a CA-MA disparity and use an inclusive strategy (see Burack, Iarocci, Flanagan, & Bowler, 2004), it is possible that the pattern of data we obtained would not hold if compared to a TD group. We found a correlation between performance on imaginative drawing tasks and MA in the ASD group, thus future work could test the planning hypothesis using a TD sample matched to the MA of the ASD participants (e.g. 8 year-olds). A further limitation is that we only used a single cognitive measure (receptive vocabulary) as a matching variable. Although prior studies of this nature also used receptive language to equate their groups (Scott & Baron-Cohen, 1996; Leeyers & Harris, 1998; Low, Goddard, & Melser, 2009), measures of non-verbal IQ could be obtained in subsequent studies to provide a fuller picture of cognitive functioning. We also caution that even though we did not find a significant group difference in the cued condition, we obtained small (but not negligible) effect sizes and the results are trending in the same direction as the spontaneous conditions. We also only detected a significant difference between the unreal category mixing conditions, but not the spontaneous and cued conditions. Thus a larger sample is required in future work to provide more robust power to discern whether such differences remain. Finally, it would be prudent to include multiple measures of low-planning tasks, rather than a single condition. Despite these limitations, our study provides evidence for the role of planning in imaginative drawing in ASD, and confirms that

imaginative difficulty does not occur at the level of representation, nor is it an effect of cognitive delay.

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Table 1

Summary of results for group differences in pass rates

Condition	Group Difference
Spontaneous	
Human	✓
Dog	✓
Cued (Template)	
Human	X
Dog	X
Hybrid	
Human-Dog	✓
Train-Car	✓
Real (Control)	
Human	X
Dog	X

✓ = yes; X = no

Table 2

Correlations between mental age (MA), chronological age (CA), Social Communication Questionnaire (SCQ) and pass rates for drawing types for the ASD group

	MA	CA	SCQ
Spontaneous Human	$r = .796^{**}$ $p < .001$	$r = .399$ $p = .125$	$r = -.384$ $p = .142$
Spontaneous Dog	$r = .564^{*}$ $p = .029$	$r = .154$ $p = .584$	$r = -.346$ $p = .206$
Cued Human	$r = .768^{**}$ $p < .001$	$r = .268$ $p = .334$	$r = -.546^{*}$ $p = .035$
Cued Dog	$r = .619^{*}$ $p = .014$	$r = .081$ $p = .775$	$r = -.383$ $p = .159$
Human/Dog Hybrid	$r = .533^{*}$ $p = .033$	$r = .063$ $p = .817$	$r = -.384$ $p = .142$
Train/Car Hybrid	$r = .278$ $p = .298$	$r = .058$ $p = .832$	$r = -.272$ $p = .309$

Appendix A

Coding Schemes

Spontaneous ‘Impossible’ Drawings. Based upon Scott and Baron-Cohen (1996), a child’s picture was scored as ‘impossible’ if body parts of the human or dog were misshapen, positioned in an incorrect place, incorrectly orientated, alien features were added or features usually present were omitted. A picture was defined as unsuccessful if none of the above ‘impossible’ features were detected and all features were correctly shaped, correctly positioned, correctly orientated, no alien features or elements were added, and if no elements that appeared on the ‘real’ drawing of the same creature were omitted.

The proportion of ‘impossible’ features drawn for each picture was also calculated following Low, Goddard and Melser (2009). The number of ‘impossible’ features for a picture was calculated and then divided by the number of overall features. An overall feature for the human was counted if it represented either of the following: head, face, body, arms and hands, legs and feet, hair or ears. A pair of legs or arms counted as a single feature and any additional features that were added, such as a tail on a human, were included as an overall feature. A feature was included as an overall feature for the dog if it represented the head, ears, face, body, front legs, back legs or tail. A feature was deemed as ‘impossible’ if it met the criteria of Scott et al. (1996) described above.

Cued ‘Impossible’ Pictures. The modified scoring system of Leavers and Harris (1998) was used for consistency with the spontaneous condition. In order for a child’s picture to be scored as ‘impossible’, the head of both the human or dog were misshapen, incorrectly orientated or positioned, alien features/elements were added to either the head or face or to other body parts on the template, or elements usually present were omitted. Elements usually present in a given entity that were omitted from the ‘impossible’ version, only allowed a

definition of ‘impossible’ if these features were present on the head/face in the ‘non-impossible’ picture of the same creature. A picture was defined as unsuccessful if no ‘impossible’ features were detected.

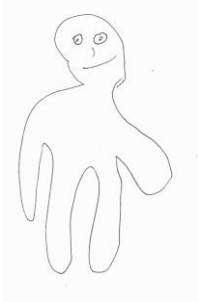

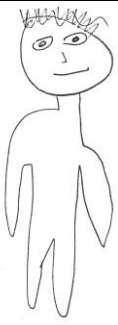

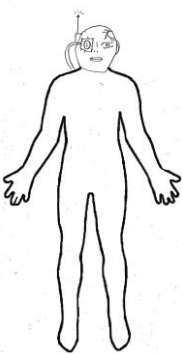
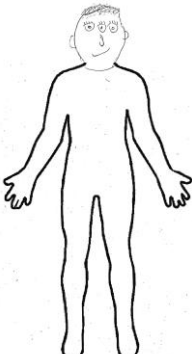

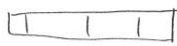

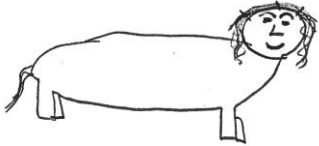
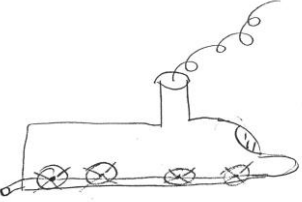
The proportion of ‘impossible’ features drawn was also calculated as per the spontaneous condition.

Unreal Category Mixing. Children’s drawings were scored as per Craig, Baron-Cohen and Scott (2001). A score of ‘pass’ was recorded if children met the criteria of indicating a single entity that fused together elements of the two primary representations (e.g. the train-car condition had to be drawn as one ‘vehicle’ including features of both a train and a car). Children failed the task if two separate real entities were drawn or the drawing depicted only one of the two real entities for example only representing the dog and consisting of no human features. The number of features drawn in each picture was also counted.

Real Pictures. Real pictures were scored for number of imaginative features as per the criteria used in the spontaneous condition in order to provide a baseline measure of whether children included impossible features in their real drawings. We also coded the number of features that changed between each child’s real picture of a human or dog and their spontaneous ‘impossible’ human or ‘impossible’ dog. The overall number of features drawn for each picture was also calculated to investigate whether children included a different number of features in their drawings dependent upon whether they were of real or ‘impossible’ entities.

Appendix B

Examples of drawings from mental age matched participants with ASD and LD

	ASD	LD
Real Human		
Spontaneous Impossible Human		
Cued Impossible Human		
Unreal Category Mixing	<div>Human/Dog</div>  <div>Train/Car</div>  	<div>Human/Dog</div>  <div>Train/Car</div> 

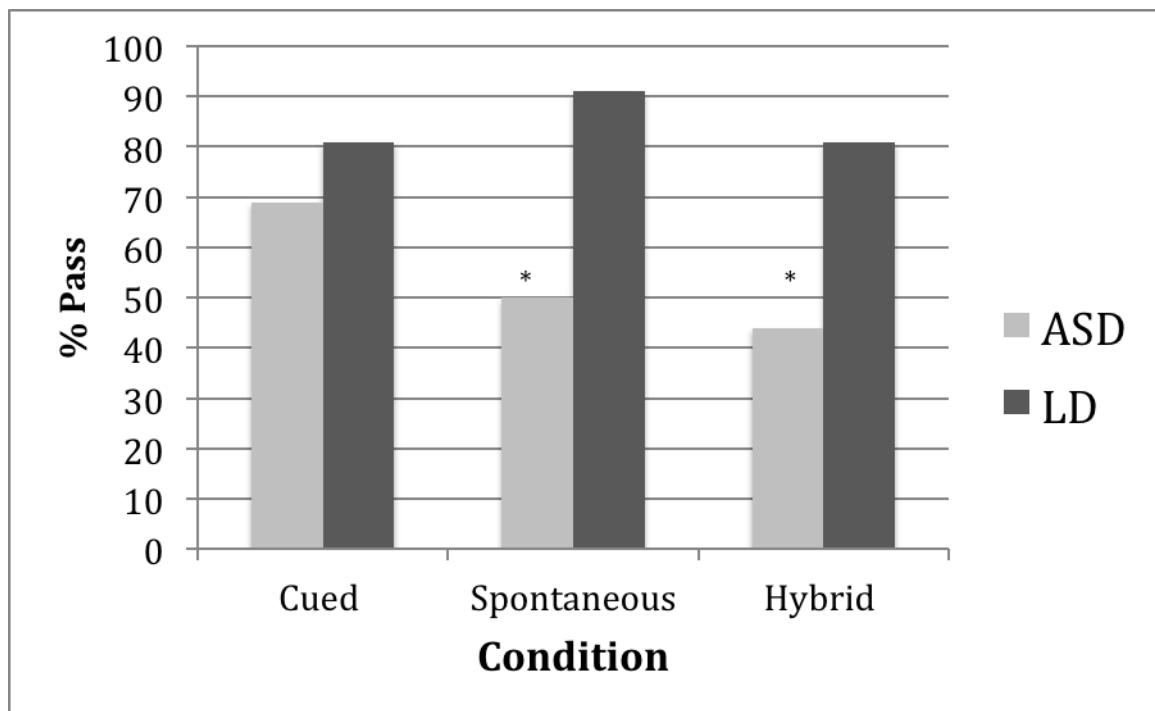


Figure 1. Percentage of children of each group (ASD and LD) able to create imaginative drawings across three conditions: low planning (cued) and high planning (spontaneous and hybrid)